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RESEARCH MEMORANDUM

THE TIME LAG BETWEEN FLAP DEFLECTION AND FORCE DEVELOPMENT AT A MACH NUMBER OF 4

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SUMMARY

An investigation of the time lag between flap deflection and force development has been made on a rectangular wing having a 9-percent-thick symmetrical circular-arc profile equipped with a full-span 30-percent-chord flap. Tests were conducted at a Mach number of 4 and a Reynolds number of 5×10^6. The data obtained from flow visualization indicated that the time lag between flap deflection and the development of the aerodynamic forces is less than one-half of a millisecond, which corresponds to less than a $3\frac{1}{2}$-chord movement of the model.

INTRODUCTION

In the operation of missiles at supersonic speeds, the controls are mechanically actuated and the rate of change of lift required to maneuver or to maintain steady flight is large and can correspond to several hundred degrees of flap deflection per second. The large rate of change of flap deflection at high speeds gives rise to the problem of the rapidity of response of a supersonic missile after a given flap deflection because of a possible time lag between the deflection of the control surfaces and the development of the aerodynamic forces.

Since changes in the aerodynamic forces are directly related to changes in shock inclination, a practical answer to the problem could be obtained through the use of high-speed photographic recordings of the actual flow past a model made visible by a schlieren system. The flow past a 9-percent-thick wing having a 30-percent-chord flap in a jet at a Mach number of 4 was therefore recorded at 1000 frames per second, while the flap deflection was changed rapidly through a 9° angle. The data obtained were examined for possible occurrence of lag in control response.

APPARATUS AND TEST METHODS

A three-dimensional wing of 4-inch span and 4-inch chord, having a 9-percent-thick circular-arc profile, was supported on a sting in the center of a 9- by 9-inch jet that operates at a Mach number of 4. The tests were conducted at a Reynolds number of 5×10^6. The angle of attack was held fixed, and the 30-percent-chord full-span flap was actuated by a sweptback strut pressing against the flap lower surface, as shown in figure 1. The schlieren photographs covering a 9-inch-diameter field of flow were recorded in a standard high-speed camera operating at 1000 frames per second. Still photographs were taken at angles of attack and flap deflections approximating the range of those obtained before and after the flap was deflected in the moving-picture sequence.

RESULTS AND DISCUSSION

Still photographs having an exposure of approximately 1 microsecond of the flow past the model at an angle of attack of -2° and flap deflections of -8° and -16° are shown in figure 2 for comparison with the motion-picture frames. The motion-picture film obtained at a rate of 1000 frames per second had an exposure time of approximately 1/4 millisecond, with a time interval between photographs of 3/4 millisecond. Selected frames from the motion-picture film are presented in figure 3, showing the change in shock inclination with changes in flap angle. These pictures start with the time at which the strut first contacts the flap (fig. 3(a)), and continue at approximately 5-millisecond intervals until the 9° flap deflection has been completed. (See figs. 3(g) and 3(h).) Examination of the original film under a coordinate-comparator showed that the airfoil was at an angle of -2° and that the flap was deflected from an initial angle of -10° to -19°. The total change in flap angle of 9° occurred in 28 milliseconds, thereby providing an average rate of change of flap angle of 320° per second. Examination of the motion-picture film frame by frame did not show any lag between flap movement and flow changes, as indicated by shock response. For example, measurements made on the frames taken in the interval from 24 to 35 milliseconds after the actuating strut contacted the flap showed (fig. 4) that the movement of the shock caused by flap deflection stopped within 1/2 millisecond after the flap stopped its upward deflection. The shock angle presented in figure 4 is actually the angle made by the straight line drawn from the point of intersection of the shock with the edge of the picture to the flap hinge line and the airfoil chord. Further proof of the absence of lag was obtained through examination of the motion-picture film by projecting it and observing the simultaneous changes in flap deflection and shock inclination.

The flow on the lower surface was not analyzed because of probable effects of the model support and the flap-actuating strut on the flow.

A simple analysis of the problem, based upon two-dimensional inviscid flow, can yield some information on time lag. If the flap could be given an infinitesimal deflection in approximately zero time, the disturbance created by the flap would move out along the shock at a velocity that is the vectorial sum of the local velocity of the flow approaching the flap and the velocity of propagation of the shock normal to the flow. As a conservative estimate, the shock can be considered to be a Mach line having a velocity of propagation normal to the flow that is equal to the velocity of sound in the fluid. Under the test conditions of the present investigation, a pressure pulse would move out along a Mach line at a velocity of 2320 feet per second, and would move from the wing-flap juncture to the outer edge of the flow field in figure 3 in 1/6 millisecond. Thus, the observed lag of between 0 and 1/2 millisecond is of the proper order. A 1/2-millisecond time lag would correspond to about a $3\frac{1}{2}$-chord movement of the model.

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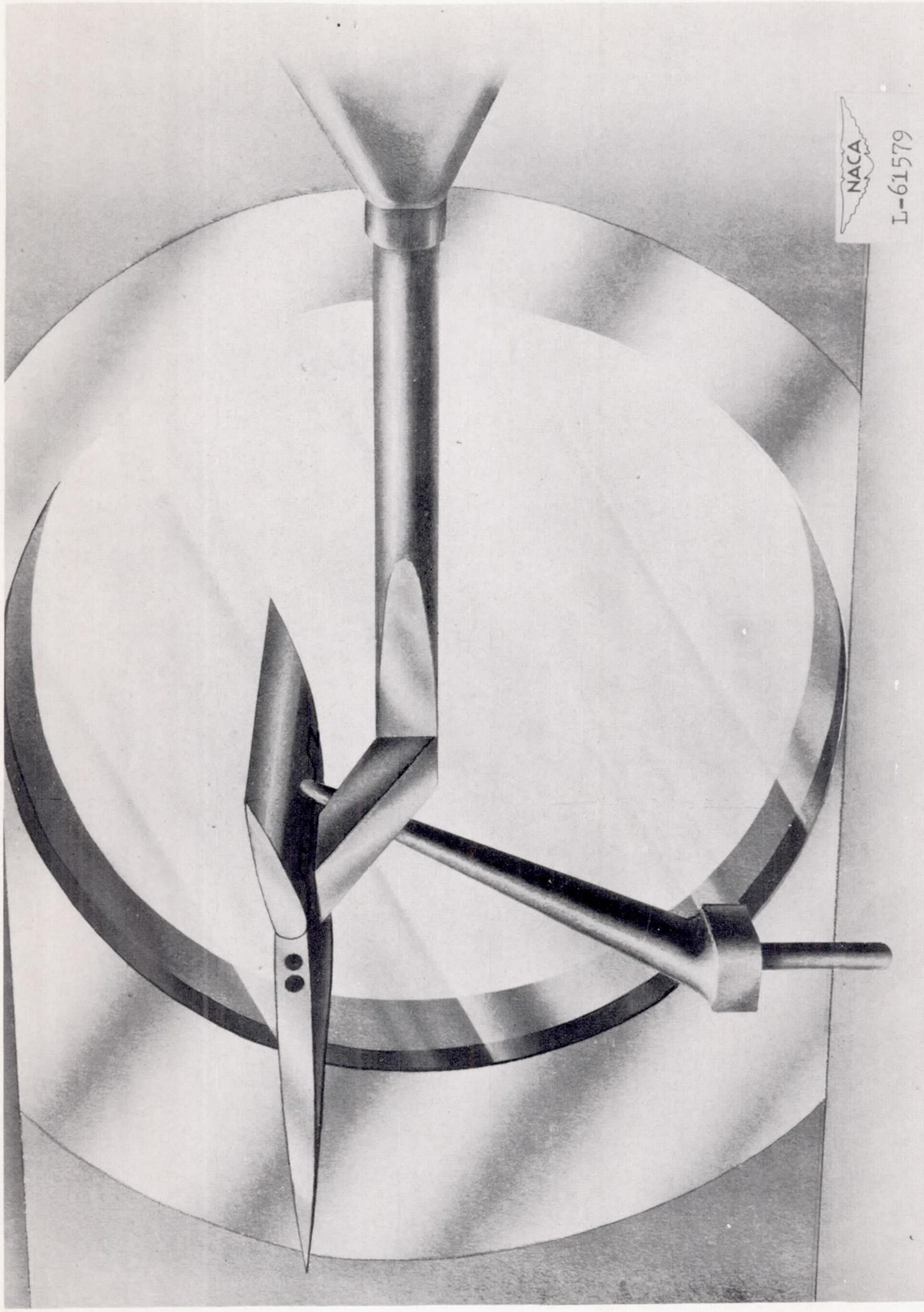
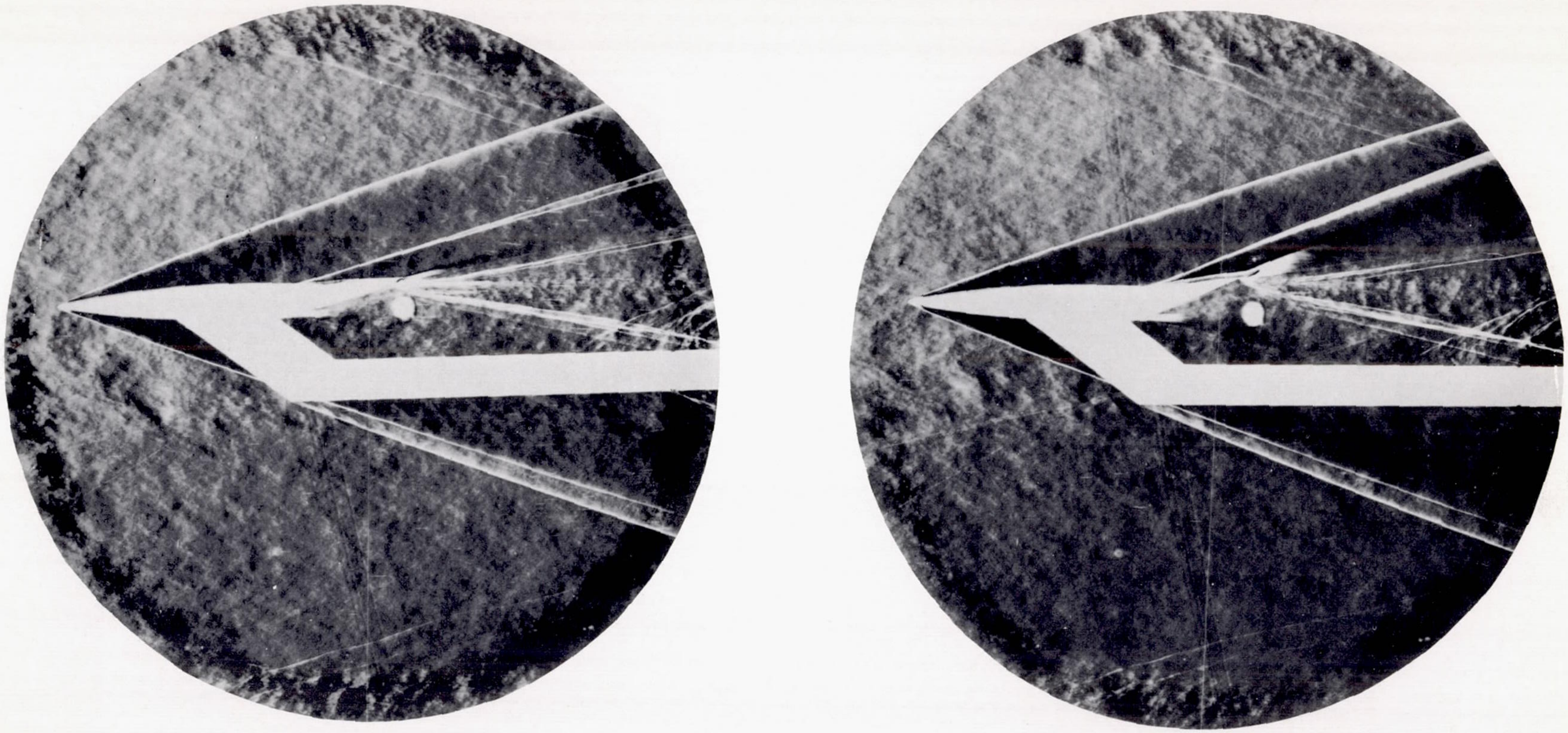


Figure 1.- Model support and flap actuator.



(a) Before; $\alpha = -2^{\circ}$; $\delta = -8^{\circ}$.

(b) After; $\alpha = -2^{\circ}$; $\delta = -16^{\circ}$.

Figure 2.- Flow past the model before and after flap deflection.

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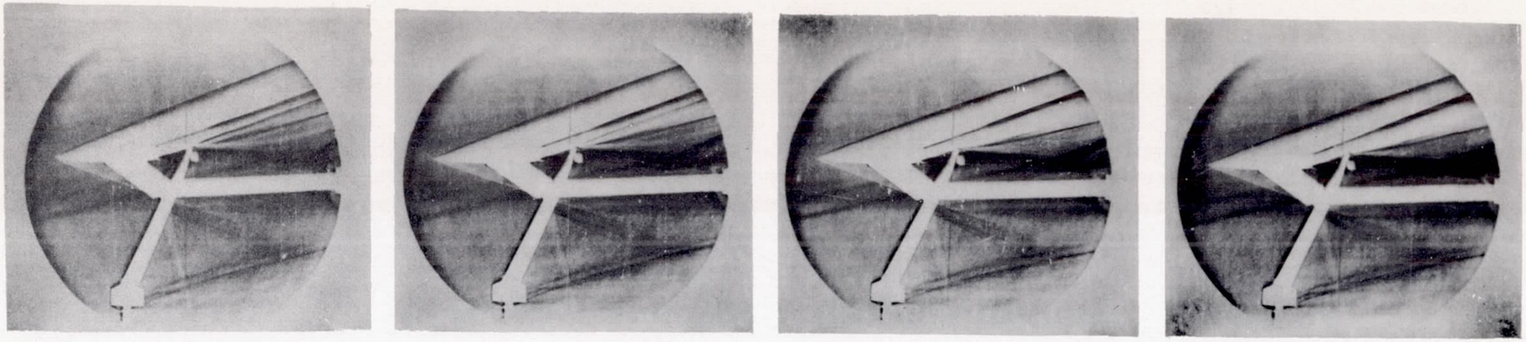
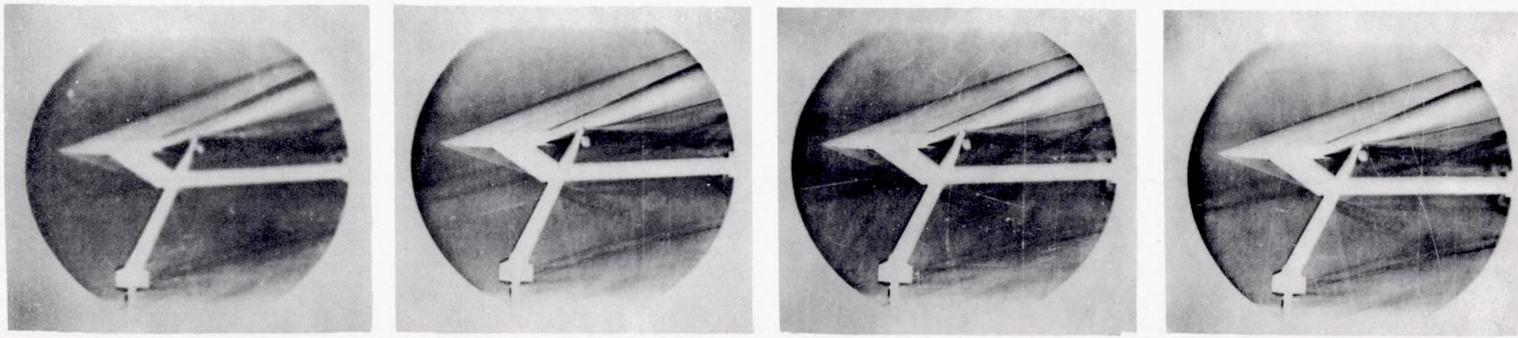


(a) Elapsed time, 0 milliseconds; flap angle, -10°.

(b) Elapsed time, 5 milliseconds.

(c) Elapsed time, 10 milliseconds; flap angle, -13°.

(d) Elapsed time, 15 milliseconds.



(e) Elapsed time, 20 milliseconds.

(f) Elapsed time, 25 milliseconds; flap angle, -17°.

(g) Elapsed time, 28 milliseconds; flap angle, -19°.

(h) Elapsed time, 32 milliseconds; flap angle, -19°.

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Figure 3.- Selected frames from the motion-picture film showing the change in flow with flap deflection and time.

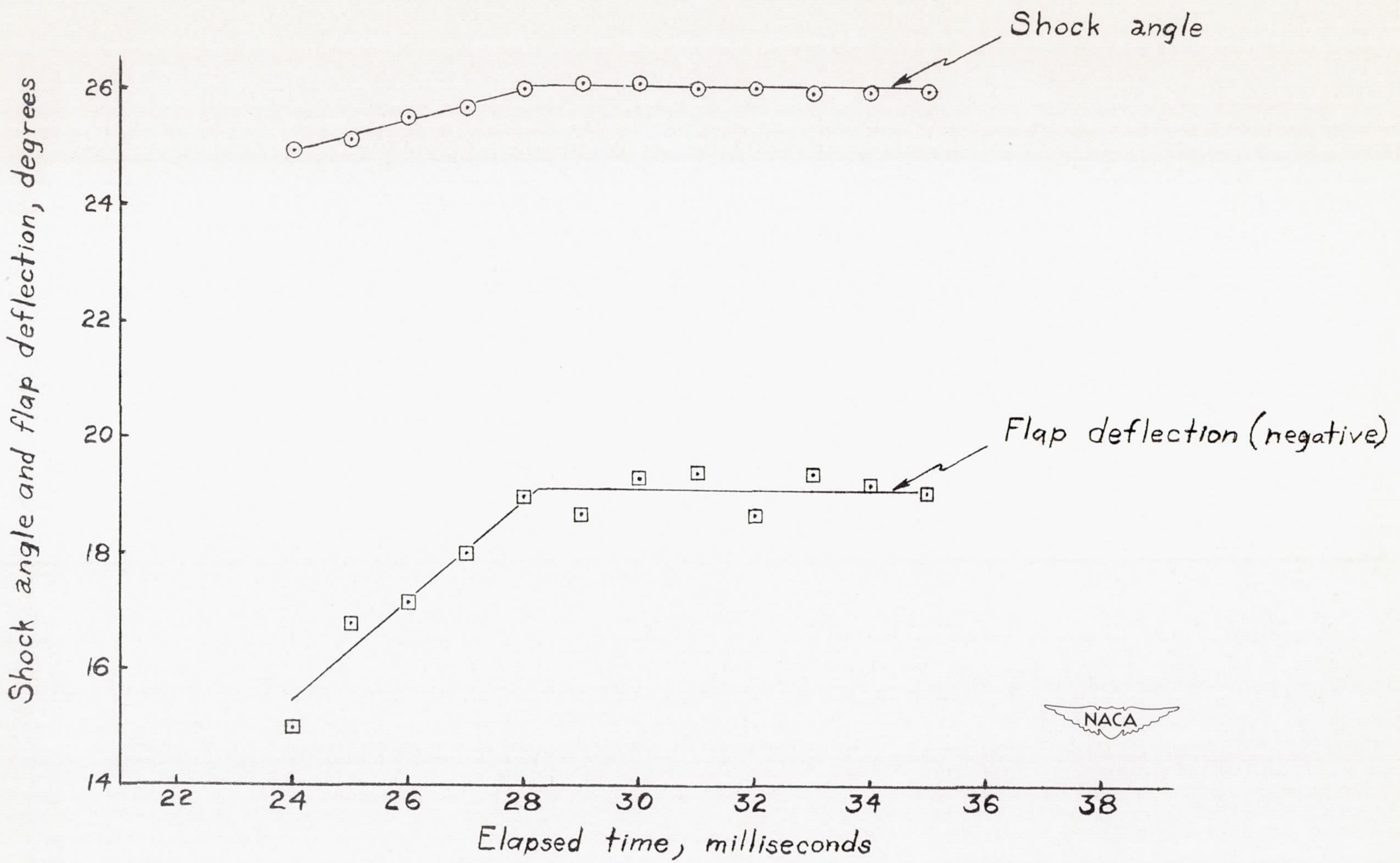

Figure 4.- Movement of the flap and the shock caused by flap deflection as flap deflection stops.

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